THE ART OF INVENTING

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There are many kinds of invention. The poet, the artist, the playwright, the novelist all exercise or may exercise invention in the production of their works. The merchant may exercise invention in the devising of a new method of selling goods. The department store was an invention of this class.

The subject of my paper is, however, the art of making technical inventions, and particularly patentable inventions. And, first, of its commercial importance; for the engineer is concerned with things having a commercial value. By the art of inventing, wealth is created absolutely out of ideas alone. It usually takes capital to develop an invention and make it productive, but not always. A notable recent example is Professor Pupin's loaded telephone line. He received a very large sum of money, and his expenditures, as I understand, were comparatively trivial.

The certificate of ownership of an invention is a patent, and the importance of the art of invention will be made apparent from a brief consideration of what rights a patent confers and of the part that patents play in the industries.

A patent is the most perfect form of monopoly recognized by the law. As was said in a recent decision:

> "Within his domain, the patentee is czar. The people must take the invention on the terms he dictates or let it alone for seventeen years. This is a necessity from the nature of the grant. Cries of restraint of trade and impairment of the freedom of sales are unavailing, because for the promotion of the useful arts the constitution and statutes authorize this very monopoly."

There is an enormous amount of wealth in this country that is based upon patents. As an instance, might be mentioned the fact that the United Shoe Machinery Company is, by means of patents, able to control the sewing machines upon which ninety per cent. of the welt shoes in the United States are sewed. The Bell Telephone Company, and the Westinghouse Air Brake Company and many other corporations of the first importance built themselves up on patents. Patents have become so well recognized a factor in commerce that, in many lines of manufacture, concerns do not depend simply upon cheapness of manufacture, or quality of product, to maintain their trade, but they count on always having a product which is at least slightly better than that of their competitors, and which is covered by patents, so that they do not have to compete with an article of equal merit. And they keep a corps of inventors at work in a constant effort to improve the product, so that, when the patents now giving protection have expired, they will have a better article to offer, which shall also be protected by patents.

Inventing has become almost a recognized profession. Many large concerns constantly employ a large corps of inventors, at liberal salaries. Besides the inventors employed by large corporations, there are many inventors who have maintained their independence, and are free lances, so to speak. Some inventors have become wealthy almost solely by their inventions, such as Edison, Bell, Westinghouse, Marconi, Pupin, Tesla, and Sprague. A considerable number of the smaller manufacturing concerns are built largely or wholly upon the inventions of their principal owners.

Aside from the question of financial returns from inventing, the inventor has the satisfaction of knowing that he is a producer of the most fundamental kind. All material progress has involved the production of inventions. Inventors are universally conceded to be among the greatest benefactors of the human race.

The art of invention is therefore one of great commercial and economical importance, and it becomes a matter of much interest to know how inventions are produced. It is my object to attempt an explanation of the manner of their production.

If it be inquired on what grounds I offer an explanation of this apparently most difficult subject, I reply that, in the prac-

tice of patent law, I have often had occasion and opportunity to inquire into the mental processes of inventors, and that the subject is one to which I have given considerable attention.

It seems to be popularly believed that the inventor must be born to his work, and that such people are born only occasionally. This is true, to a certain extent, but I am convinced there are many people who, without suspecting it, have latent inventive abilities, which could be put to work if they only knew how to go about it. The large percentage of inventors in this country compared with all other countries, shows that the inventive faculty is one which can be cultivated to some extent. The difference in ingenuity is not wholly a matter of race, for substantially the same blood exists in some other countries, but it is the encouragement of our patent laws that has stimulated the cultivation of this faculty.

The popular idea seems to be that an invention is produced by its inventor at a single effort of the imagination and complete, as Minerva sprang full grown and fully armed from the mind of Jove.

It is, undoubtedly, true that every inventor must have some imagination or creative faculty, but, as I shall seek to show, this faculty may be greatly assisted by method. While reasoning does not constitute the whole of an inventive act, it can, so to speak, clear the way and render the inventive act easier of accomplishment.

Invention has been defined as "In the nature of a guess; the mind leaps across a logical chasm. Instead of working out a conclusion, it imagines it." The courts have repeatedly held that that which could be produced *purely* by the process of reasoning or inference, on the part of one ordinarily skilled in the art is not patentable, but that the imaginative or creative faculty must somewhere be used in the process. The mind must somewhere leap from the known to the unknown by means of the imagination, and not by mere inference in making the invention. But the inventor, consciously or unconsciously, by proper method, reduces the length of this leap to much more moderate proportions than is popularly supposed.

That reasoning and research frequently enter very largely into the inventive act in aid of the creative faculty is the opinion of Dr. Trowbridge, of Columbia University who said:

"Important inventions leading to widespread improvements in the arts or to new industries do not come by chance, or as sudden inspira-

tion, but are in almost every instance the result of long and exhaustive researches by men whose thorough familiarity with their subjects enables them to see clearly the way to improvements. Almost all important and successful inventions which have found their way into general use and acceptance have been the products of well-balanced and thoughtful minds, capable of patient laborious investigation."

Judge Drummond, in a decision many years ago, said:

"Most inventions are the result of experiment, trial, and effort, and few of them are worked out by mere will."

Most inventions are an evolution from some previously invented form. It has been said:

"We know exactly how the human mind works. The unknown—or unknowable—it always conceives in terms of the known."

Even the imagination conceives in terms of what is already known; that is, the product of the imagination is a transformation of material already possessed. Imagination is the association in new relations of ideas already possessed by the mind. It is impossible to imagine that, the elements of which are not already known to us. We cannot conceive of a color which does not consist of a blending of one or more colors with which we are already familiar. This evolution of an invention is more or less logical, and is often worked out by logical processes to such an extent that the steps or efforts of imagination are greatly reduced as compared with the effort of producing the invention solely by the imagination.

Edison is quoted as having said that "any man can become an inventor if he has imagination and pertinacity," that "invention is not so much inspiration as perspiration."

There are four classes of protectable inventions. These are

Arts,

Machines,

Manufactures, and

Compositions of matter.

In popular language an art may be said to be any process or series of steps or operations for accomplishing a physical or chemical result. Examples are, the art of telephoning by causing undulations of the electric current corresponding to the sound waves of the spoken voice. The art of casting car wheels, which consists in directing the metal into the mold in a stream running tangentially instead of radially, so that the metal in the mold is given a rotary movement, and the heavy, sound metal flows out to the rim of the wheel, while the light

and defective metal is displaced toward the centre, where it is not subjected to wear.

The term machine hardly needs any explanation. It may be said to be an assemblage of two or more mechanical elements, having a law of action of its own.

A manufacture is anything made by the hand of man, which is neither a machine nor a composition of matter; such as, a chisel, a match, or a pencil.

The term composition of matter covers all combinations of two or more substances, whether by mechanical mixture or chemical union, and whether they be gases, fluids, powders or solids; such as, a new cement or paint.

These definitions are not legally exact, but serve to illustrate the meaning.

In the making of all inventions which do not consist in the discovery of the adaptability of some means to an end not intentionally being sought after, the first step is the selection of a problem. The inventor should first make certain that the problem is based upon a real need. Much time and money is sometimes spent in an effort to invent something that is not really needed. What already exists is good enough or is so good that no additional cost or complication would justify anything better. The new invention might be objectionable because it would involve counter disadvantages more important than its own advantages, so that a really desirable object is the first thing to be sure of.

Having selected a problem, the next step should be a thorough analysis of the old situation, getting at the reasons for the faults which exist, and in fact discovering the presence of faults which are not obvious to others, because of the tendency to believe that whatever is, is right.

Then the qualities of the material, and the laws of action under which one must operate should be exhaustively considered. It should be considered whether these laws are really or only apparently inflexible. It should be carefully considered whether further improvement is possible in the same direction, and such consideration will often suggest the direction in which further improvement must go, if a change of direction is necessary. Sometimes the only possible improvement is in an opposite direction. A glance at the accounts of how James Watt invented the condensing steam-engine will show what a large part profound study of the old engine and of the laws of steam

played in his invention, and how strongly they suggested the directions of the solutions of his difficulties.

We now come to the constructive part of inventing, in order to illustrate which, I will seek to explain how several inventions were, or could have been, produced.

The way in which the first automatic steam engine was produced was undoubtedly this—and it shows how comparatively easily a really great invention may sometimes be made. It was the duty of Humphrey Potter, a *boy*, to turn a stop-cock to let the steam into the cylinder and one to let in water to condense it at certain periods of each stroke of the engine, and if this were not done at the right time, the engine would stop. He noticed that these movements of the stop-cock handles took place in unison with the movements of certain portions of the beam of the engine. He simply connected the valve handles with the proper portions of the beam by strings, and the engine became automatic—a most eventful result.

As one example of the evolution of an invention, I will take an instrument for measuring and recording a period of time, known as the calculograph, because it lends itself with facility, to an explanation from a platform and because my duties as a lawyer have necessitated my becoming very familiar with the invention, and have caused me to consider how it was probably produced.

And first the problem: There was much occasion to determine and record the values of periods of elapsed time; such as, the length of time of a telephone conversation; as the revenue of the telephone companies depended upon the accuracy of the determination. All the previous methods involved the recording in hours and minutes the times of day marking the initial and the final limits of the period to be measured, and then the subtraction of the one time of day from the other. This subtraction was found to be very unreliable as well as expensive. The problem then was to devise some way by which the value of the period could be arrived at directly and without subtraction and also by which such value could be mechanically recorded.

The prior machine from which the calculograph was evolved is the time-stamp, a printing machine having a stationary die like a clock dial and having a rotating die like the hand of the clock, as in Fig. 1. The small triangle outside the dial is the hour hand, it being placed outside the dial because it is necessary

that the two hands shall be at the level of the face of the dial and yet be able to pass each other. The hour hand may be disregarded here, as the records needed are almost never an hour long. The manner of using the time stamp to determine the value of an interval was to stamp the time of day at the beginning of the period, and then to stamp the time of day at the close of the period at another place on the paper, as shown in Fig. 2, and finally mentally to subtract the one time of day from the other to get the value of the period.

The inventor of the new machine conceived the idea that, if the time-stamp were provided with guides or gauges so that the card could be placed both times in the same position, and

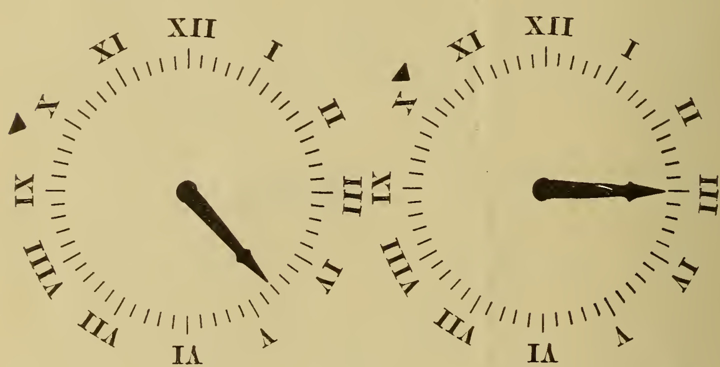
Fig. 1.
Time Stamp Record.

the two records of the time stamp thus be superimposed concentrically (as illustrated in Fig. 3), the value of the period would be represented by the arc marked off by the initial and final imprints of the minute hand, so that, instead of subtracting one record from another, he had only to find the value of the arc marked off by counting the corresponding number of minutes along the dial.

The inventor had thus gotten rid of the subtraction, but there were several desirable qualities not yet obtained. First, he could not tell from the record alone, whether it was the longer or the shorter arc marked off that was the measure of the period. For instance, he could not tell whether the period was 7 or 53 minutes. This was because the two hand or pointer im-

prints were exactly alike except in position. So he conceived the idea of making the pointer imprints different in appearance, by providing the pointer die with a mark in line with the pointer, as illustrated in Fig. 4.

The mark and pointer revolve together and either the dies or the platen are so arranged that the mark can be printed without the pointer at the initial imprint and the pointer at the final imprint as in Fig. 5, the mark being printed or not at the final imprint, as desired. This could be done either by allowing the pointer die or the corresponding portion of the platen to remain retracted from the paper during the first printing.



9:23 Fig. 2. 10:15

Initial Time Stamp Record. Final Time Stamp Record.

Elapsed Time: 10:15 − 9:23 = 52 minutes.

To read this record, hours and minutes must be subtracted from hours and minutes, an operation liable to much error.

It could thus be told with certainty from the record alone whether the longer or the shorter arc is the measure of the period, because the beginning of the arc is that indicated by the imprint of the mark without the pointer.

There was still something to be desired. The counting of the minutes along the measuring arc was a waste of time, if the value of the arc could in some way be directly indicated. If the hand were set back to 12 o'clock for the initial imprint, the final imprint would show the hand pointing directly at the minute whose number on the dial is the value of the period' and it would not even be necessary to count. But the setting

of the hand back to zero would prevent its making the final imprint of any previously begun record, so that the machine could only be used for one record at a time. It was desirable

Fig. 3.
Subtraction eliminated but counting still required and uncertainty whether elapsed period is 7 or 53 minutes.

to have a machine that would record any number of overlapping intervals at the same time, so that one machine would record the intervals of all the telephone conversations under the control of a single operator, or rather of two operators, because

Fig. 4.
Hand and zero mark revolving within stationary dial.

both of them could reach the same machine. So it wouldn't do to set the hand back to zero, as the hand must rotate constantly and uniformly. Then why not set the zero up to the

hand at each initial imprint? This meant making the dial rotatable, as well as the hand. It gave an initial record like that shown in Fig. 6.

The inventor then thought of securing the dial to the pointer die so that they would revolve together, the zero of the dial being in line with the pointer, as illustrated in Fig. 7. This would obviate the necessity of setting the zero of the dial up to the pointer at the initial imprint.

But again the improvement involved a difficulty. As the dial rotated, its final impressions would never register with its initial impressions and would therefore always destroy them. As the first imprint of the dial was the only useful one, and as

FIG. 5.

Initial imprint of zero mark alone and final imprint of hand (and zero). Elapsed time, 8 minutes. No subtraction and no uncertainty as to which imprint first, but counting still required.

the second imprint only made trouble, the inventor conceived the idea of not making any imprint of the dial at the close of the period, and this he accomplished by making the annular portion of the platen covering the dial so that it could be advanced to print or not as desired. As the zero of the dial always marked the beginning of the measuring arc, it served the same purpose as the mark in line with the pointer, and the latter could now be omitted.

The final machine then consists simply of a revolving die which, as shown in Fig. 8, consists of a graduated and progressively numbered dial, having a pointer revolving in line with the zero, and the machine has a platen consisting of an

inner circular portion over the pointer and an annular portion over the dial, each portion being operated by a separate handle so that the dial can be printed at the beginning of the period and the pointer alone, at its close.

The final record has an initial imprint of the dial, Fig. 9a, the zero of the dial showing the position of the pointer at the beginning of the period, and a final imprint of the pointer alone, as shown in Fig. 9b, the complete final record, Fig. 9c, consisting of the superimposition of these two records, and showing the pointer in line with that graduation whose number is the value of the period. Here is a record not only involving no subtraction and no uncertainty but not even, counting in its record,

Fig. 6.

Dial moved up to initial position of zero mark. Elapsed time, 11 minutes. No subtraction, no counting, no uncertainty; but only one record possible at a time.

and, as it was made without disturbing the motions either of the pointer or dial, any number of records of other periods could have been begun or finished while the machine was measuring the period in question.

Hiding all the intermediate steps in the evolution of this invention, it seems the result of spontaneous creation, but considering the steps in their successive order, it will be seen that the invention is an evolution from the time-stamp; that logic rendered the effort of the imagination at any one step small by comparison, and that the individual steps might be well within the capacity of a person to whom the spontaneous creation of the final invention might be utterly impossible.

A most interesting example of the evolution of an invention is that of the cord-knotter of the self-binding harvester. The problem here was to devise a mechanism which would take place

Fig. 7.
Dial with pointer at zero revolving together.

of the human hands in tying a knot in a cord whose ends had mechanically been brought together around a bundle of grain.

The first step was to select the knot which could be tied

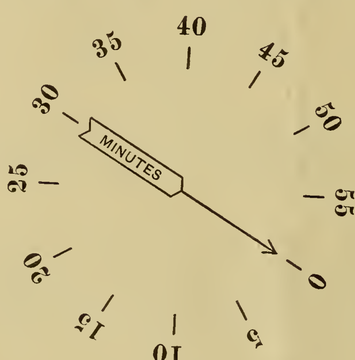


Fig. 8.
Dial with pointer at zero revolving together, zero mark on pointer being replaced by zero of dial.

by the simplest motions. The knot which the inventor selected is that shown in Fig. 10, and is a form of bow-knot.

The problem was to find how this knot could be tied with the smallest number of fingers, making the smallest number

of simple movements. As anyone would ordinarily tie even this simple knot, the movements would be so numerous and complex as to seem impossible of performance by mechanism. The inventor, by study of his problem, found that this knot could be tied by the use of only two fingers of one hand, and

Fig. 9a.
Initial Imprint.

Fig. 9b.
Final Imprint.

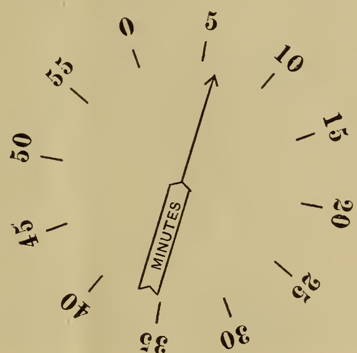


Fig. 9c.
Complete Record.

Simple, direct-reading record. No subtraction, no counting, no uncertainty. Any number of overlapping periods recorded on one machine.

by very simple movements. The knot will best be understood by following the motions of these fingers in tying the knot. Using the first and second fingers of the right hand, they are first swept outward and backward in a circular path against the two strands of the cord to be tied, as shown in Fig. 11.

The fingers continue in their circular motion backward, so that the strands of the cord are wrapped around these fingers, as shown in Fig. 12.

Continuing their circular motion, the fingers approach the strands of the cord between the twisted portion and a part of the machine which holds the ends of the cord, and the fingers spread apart as shown in Fig. 13, so that they can pass over

FIG. 10.

and grasp the strands thus approached, as shown in Fig. 14.

The fingers then draw back through the loop which has been formed about them, the fingers holding the grasped portion of the strands, as shown in Fig. 15.

The knot is finished by the completion of the retracting movement of the fingers through the loop, thus forming the bow of the knot as shown in Fig. 16.

The inventor found that one finger could have a purely rotary movement, as if it were fixed on the arm and unable to move independently of the arm, and the movement being as if the arm rotated like a shaft, but the second finger must be further capable of moving toward and from the first finger to perform the opening movement of Fig. 13, and the closing movement of Fig. 14 by which it grasps the cord. The inventor accordingly, from his exhaustive analysis of his problem,

Fig. 11.

and his invention or discovery of the proper finger motions, had further only to devise the very simple mechanical device illustrated in Fig. 17 to replace his fingers.

The index finger of the hand is represented by the finger S, which is integral with the shaft V. The second finger of the hand is represented by the finger U, which is pivoted to the first finger by the pin s. The grasping movement of the finger U is accomplished by a spring V' bearing on the shank U',

and its opening movement is caused by the travel of an anti-friction roll U'', on the rear end of the pivoted finger, over a cam V'', on the bearing of the shaft. The shaft is rotated by the turning of a bevel pinion W on the shaft through the action of an intermittent gear. The necessity of drawing the fingers backward to accomplish the movement between Figs. 14 and 16 was avoided by causing the tied bundle to have a motion away

Fig. 12.

from the fingers as it is expelled from the machine, the relative motion between the fingers and the knot being the same as if the fingers drew back.

Thus the accomplishment of a seemingly almost impossible function was rendered mechanically simple by an evolution from the human hand, after an exhaustive and ingenious analysis of the conditions involved.

It will be seen from the examples I have given that the constructive part of inventing consists of evolution, and it is the association of previously known elements in new relations (using the term elements in its broadest sense). The results of such new association may, themselves, be treated as elements of the next stage of development, but in the last analysis nothing is invented or created absolutely out of nothing.

FIG. 13.

It must also be apparent, that pure reason and method, while not taking the place of the inventive faculty, can clear the way for the exercise of that faculty and very greatly reduce the demands upon it.

Where it is desired to make a broadly new invention on fundamentally different lines from those before—having first studied the art to find the results needed, the qualities of the material or other absolutely controlling conditions should

be exhaustively considered; but at the time of making the inventive effort, the details should be dismissed from the mind of how results already obtained in the art were gotten. One should endeavor to conceive how he would accomplish the desired result if he were attempting the problem before any one else had ever solved it. In other words, he should endeavor to provide himself with the idea elements on which the im-

FIG. 14.

agination will operate, but to dismiss from his mind as much as possible the old ways in which these elements have been associated, and thus leave his imagination free to associate them in original and, as to be hoped, better relations than before. He should invent all the means he can possibly invent to accomplish the desired result, and should then, before experimenting, go to the art to see whether or not these means have before

been invented. He would probably find that some of the elements, at least, have been better worked out than he has worked them out. Of course, mechanical dictionaries, and other sources of mechanical elements and movements will be found useful in arriving at means for accomplishing certain of the motions, if the invention be a machine. Many important inventions have been made by persons whose occupation is

Fig. 15.

wholly disconnected with the art in which they are inventing, because their minds were not prejudiced by what had already been done. While such an effort is likely to possess more originality than that on the part of a person in the art, there is, of course, less probability of its being thoroughly practical. The mind well stored with the old ways of solving the problem will, of course, be less likely to repeat any of the mistakes of the earlier inventors, but it will also not be as apt to strike out on

distinctly original lines. It is so full, already, of the old forms of association of the elements as to be less likely to think of associating them in broadly new relations.

Nothing should be considered impossible until it has been conclusively worked out or tried by experiments which leave no room for doubt. It is no sufficient reason for believing a thing won't work because immemorial tradition, or those skilled in

Fig. 16.

the art, say it will not work. Many an important improvement has been condemned as impracticable, by those in the art, before it has been tried.

A conception which an inventor has been striving for unsuccessfully will sometimes come to him at a time of unaccustomed mental stimulation. The slight stimulation of the movement of a train of cars, and the sound of music, have

been known to produce this effect. The sub-conscious mind, after having been prepared by a full consideration of the problem to be solved, will sometimes solve the problem without conscious effort, on the part of the inventor.

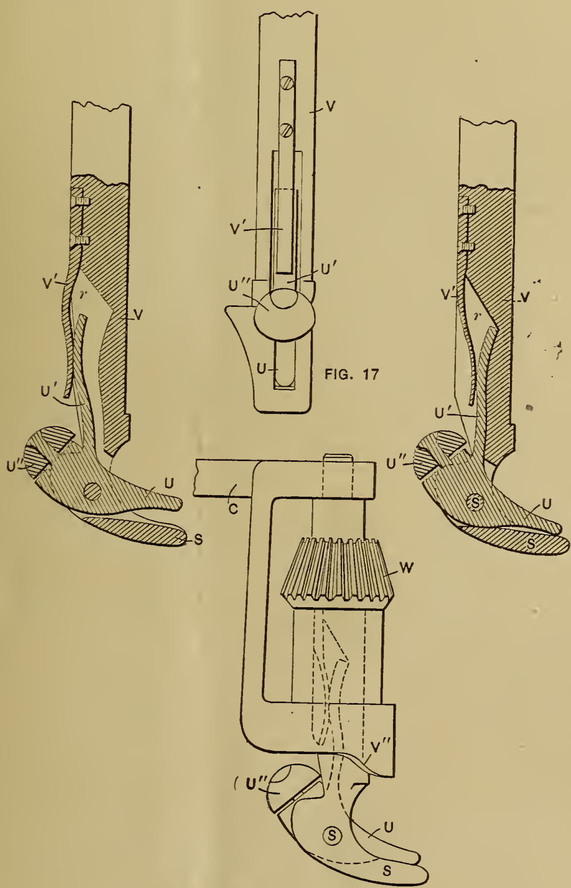


Fig. 17.
The essential parts of the cord-knotter.

In inventing a machine to operate upon any given material, the logical way is to work from the tool to the power. The tool or tools should first be invented, and the motions determined which are to be given to them. The proper gearing or parts

to produce from the power each motion for each tool should then be invented. It should then be considered if parts of each train of gearing cannot be combined, so as to make one part do the work of a part in each train; in short, to reduce the machine to its lowest terms. Occasionally a mechanism will be invented which is exceedingly ingenious, but which it is afterwards seen how to simplify, greatly at the expense of its apparent ingenuity. This simplification will be at the sacrifice of the pride of the inventor, but such considerations as cheapness, durability and certainty of action leave no choice in the matter. It will sometimes be found that a single part can be made to actuate several parts, by the interposition of elements which reverse the motion taken from such part, or which take only a component of the motion of such part, or the resultant of the motion of such part and some other part. Where a machine involves the conjoint action of several forces, it can be more thoroughly studied, if it is found there are positions of the machine in which one force or motion only is in operation, the effect of the others in such position being eliminated, and thus the elements making up the resultant effect can be intelligently controlled.

The drawing board can be made a great source of economy in producing inventions. If the three principal views of all the essentially different positions of the parts of a machine are drawn, it will often be found that defects will be brought to light which would not otherwise have been observed until the machine was put into the metal.

It is desirable to see the whole invention clearly in the mind before beginning to draw, but if that cannot be done, it is often of great assistance to draw what can be seen, and the clearer perception given by the study of the parts already drawn, assists the mind in the conception of the remaining parts.

If the improvement which it is sought to make is a process, it should first be considered whether any radically different process can be conceived of, and if so, whether or not it is better than the old process, and the reason for its defects, and whether it is possible to cure those defects. If the old process appears to be in the right general direction, it should be considered whether one of the old steps cannot with advantage be replaced by a new one, or whether the order of performing the steps cannot be changed to advantage. I have in mind one process in which a reversal of the order of steps resulted in giving the product

certain desirable qualities which had before been sought for, but could not be obtained.

It is sometimes desirable not only to invent a good process of producing a product, but to control all feasible processes of producing the product. Such a case occurred where the product itself had been patented, and it was desirable to extend the monopoly beyond the time when the patent on the product should expire. There were two steps or operations which were essential to the production of the product, and the inventor, by reference to permutations, saw that there were but three orders in which those steps could be performed; first, the order A-B, then the order B-A, and then both steps together. The order A-B was the old order, which did not produce an article having the desired qualities. The inventor therefore, proceeded to invent ways by which the steps could be performed together, and then by which they could be performed in the reverse order, and the patenting such two processes would cover generically all possible ways of making the article and secure the desired result of putting himself in position to control the monopoly after the patent on the article had expired, because no one could make the article without using one of his two processes.

In inventing compositions of matter there is one inventor who, if he is seeking for a certain result, will take a chemical dictionary and make every possible combination of every substance that could by any possibility be an ingredient of that which he desires to produce. It is as if he were seeking to locate a vein of mineral in a given territory, and, instead of observing the geographical and geological formation, and thus seeking to arrive at the most probable location of the vein, he should dig up every foot of earth throughout the whole territory, in order finally to locate the vein. This method is exceedingly exhaustive, but does not appeal to one as involving much exercise of the inventive faculties.

Inventing has become so much of a science, that if one is willing to spend sufficient time and money to enable a competent corps of inventors to go at the matter exhaustively, almost any possible invention involving but a reasonable advance in the art can be perfected.